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FOULING AND BORING OF GLASS REINFORCED PLASTIC - Balsa
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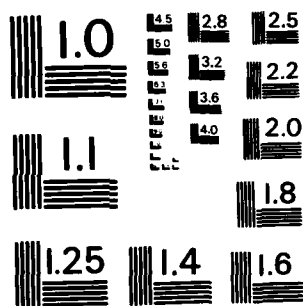
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REPORT

MRL-R-874

FOULING AND BORING OF
GLASS REINFORCED PLASTIC - Balsa Blocks
IN A TROPICAL MARINE ENVIRONMENT

J.A. Lewis and D.J. Hall

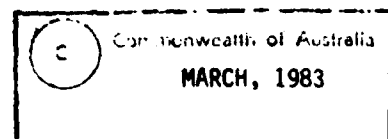
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ABSTRACT

Test blocks constructed of balsa wood coated on each side with a layer of glass-reinforced plastic (GRP) were exposed in a tropical marine harbour for 14 months. Undamaged controls and blocks with simulated minor and major damage to the GRP coating were either fully or half immersed. Molluscan borers, mostly teredinids, penetrated and damaged the balsa cores of all blocks examined, with greatest damage to fully-immersed major damage blocks. Fouling growth covered all submerged GRP surfaces but had no apparent effect on the coating.

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FOULING AND BORING OF
GLASS REINFORCED PLASTIC - Balsa BLOCKS
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1. INTRODUCTION

The hull construction of the Royal Australian Navy's replacement Minehunter is to consist of a rigid, high strength core material sandwiched between skins of glass-reinforced plastic (GRP). Of concern to Navy is the ability of these materials to withstand marine exposure, particularly in a damaged state.

The RAN's "Ton" class minesweepers, to be replaced by the new Minehunter, have hulls constructed of West African mahogany (Kyaya ivorensis). This timber is susceptible to attack by marine borers and the hulls therefore required a coating able to resist such attack. The borer resistance of various organic coating systems was evaluated in earlier studies at MRL and a number of these found suitable [1]. Glass reinforced epoxy resin was selected for use on the Australian ships.

This report presents preliminary results from a trial to evaluate the performance and borer resistance of GRP sandwich materials proposed for use in hull construction of the new Minehunter. In particular the trial was planned to compare the performance of balsa wood with two types of PVC foam (Appendix A) as core materials under different degrees of immersion and with varying degrees of damage to the GRP coating.

After twelve months of the potential 5-year trial, some balsa blocks showed signs of internal borer damage. These blocks were removed and returned to MRL for detailed examination. The results of this examination are now reported.

2. MATERIALS AND METHODS

a. Specimen Preparation

Two sides of the foam or balsa sheets were covered with a layer, 8-9mm thick, of glass-reinforced polyester resin. Appendix B contains details of materials used and skin lay-up. Test blocks measuring 150 X 100 X 78mm were cut from the large sheets and the edges sealed with the same polyester

resin used for skin laminations. Four sets of test blocks were prepared: major damage, minor damage, undamaged and painted. Major damage blocks had a 50mm diameter hole drilled through the GRP into the core material on one side of the block and minor damage blocks a 12mm diameter hole through the GRP skin but not into the core material. Painted blocks were given a coating of barrier (CDL 188/71) and antifouling (Dulux Black 828-14514) paint.

b. Marine Exposure

Test blocks were exposed at Mourilyan Harbour (17°36'S, 146°7'E) in North Queensland. Two blocks from each set were fully immersed at a depth of 1.5m and two half immersed in the water below the Joint Tropical Trials and Research Establishment raft. Blocks were also attached to the shore boat ramp to be alternately immersed and exposed by the ebb and flood of the tides. Blocks of foam and balsa unprotected by GRP were also immersed. All test blocks were initially immersed on 22 September 1980.

Blocks were inspected twice weekly during the first four weeks of immersion, weekly for the next eight weeks and monthly thereafter. During inspections unpainted blocks were removed from exposure, visually examined, the fouling and superficial water removed, and then the blocks weighed to assess ingress of water. Painted panels were inspected for fouling settlement. Weighing of unpainted panels was discontinued after six months because of the difficulty in removing the heavy build-up of fouling without damaging the test blocks.

After twelve months some of the balsa-cored blocks showed external signs of borer damage. These blocks (Table 1) were withdrawn from exposure on 25 November 1981 and returned to MRL.

c. Biological Assessment

On return to MRL, blocks were photographed and preserved in seawater-formaldehyde. The abundances of the major groups of fouling organisms on external surfaces were determined using a point-intercept method. Two sets of fifty random points were marked on clear plastic overlays the size of block faces. For each GRP face, and for each overlay, the presence or absence of organisms under each point was scored. The total presence score for each organism group on each face estimates percentage surface cover for that group on that face. Fouling was then scraped from the GRP faces, dried and weighed.

After fouling assessment, panels were radiographed to determine the presence and extent of borer damage. Damaged panels were then sawn along two planes parallel to the block faces and animal remains removed for identification. Borers were identified using descriptions and illustrations in Turner [2] and Marshall Ibrahim [3]. Estimates of damage to each cut face were made by tunnel counts and estimates of percentage wood loss. Wood loss estimates were derived by the same method used to assess fouling cover. Values from replicate blocks were averaged and the results compared statistically by analysis of variance, standard t and Welch-Aspin tests where appropriate [4]. Arcsine transformations were applied to percentages and

logarithmic transformations to tunnel numbers prior to analysis [4]. Significant pairs were separated after analysis of variance using the Newman-Keuls method [4].

For comparison with balsa-cored blocks two major-damage, foam-cored (one 'Airex', one 'Klegacell') blocks were withdrawn from full immersion on 13 April 1982. These were air-freighted to MRL, radiographed and returned to Mourilyan Harbour for reimmersion.

3. RESULTS

a. Fouling Growth

The surfaces of full-immersed blocks were almost covered by a diverse assemblage of plants and animals (Tables 2,3). Half-immersed blocks were only fouled below the water line, mainly by diminutive algae and a slime film of undetermined composition (possibly bacteria, diatoms and organics) (Tables 2,4).

There was no statistically-significant difference in fouling cover or dry weight among full-immersed blocks but both parameters differed significantly ($p < 0.01$) between fully- and half-immersed blocks. There was no evidence of any damage to the GRP coating by the fouling organisms.

b. Borer Damage

All balsa-cored blocks examined had been penetrated and damaged to varying extents by molluscan borers (Plates 1,2). The soft parts of the borers had decomposed prior to examination of the blocks but eight molluscan species were identified from hard parts (palleys and shells) found in the tunnels (Table 5). In fully-immersed blocks both tunnel numbers and percentage wood loss were significantly higher ($p < 0.01$) in the major than in the minor or undamaged blocks (Table 6). Tunnel numbers and wood loss were also significantly higher ($p < 0.05$) in the fully-immersed, major-damage blocks than in the half-immersed blocks (Table 6).

In minor and undamaged blocks infection occurred along the edges perpendicular to the block faces. Tunnels were therefore concentrated at the corners and spread out from these regions (Plates 1a,b, 2a,b). Where blocks had been internally bonded with PVA adhesive, the borers seemed unable to penetrate the glue line and were therefore confined to bonded segments of balsa containing an infection point (see Plate 2a,b). As is typical of teredinid borers [4], tunnels were orientated along the grain of the wood. At the balsa-GRP interface tunnels turned through 180° and headed back into the wood. Major-damage panels also showed corner infection but most tunnels were initiated from the hole drilled through the GRP coating (Plates 1c, 2c). Tunnels in the half-immersed panels were confined to the immersed half of the blocks (Plates 1d, 2d).

Radiographs of foam-cored blocks showed no evidence of borer damage (Plate 3).

4. DISCUSSION

a. Borers

Marine wood-boring animals are either crustacean arthropods or bivalve molluscs and these differ in their boring habit and subsequently the type of damage they cause. Crustacean borers excavate tunnels several centimetres into or just below the wood surface and cause a progressive breakdown of the outer wood layers whereas molluscan borers can bore deep into the wood and riddle a superficially sound structure [5,6]. The zone of attack also varies as crustacean borers live mainly in the intertidal zone [7] whilst the molluscs rarely settle above mid-tide level and numbers tend to increase with depth [3,8].

No crustacean borers were found in the GRP-Balsa blocks but both families of wood-boring molluscs were represented: the Pholadidae by *Martesia striata* and the Teredinidae by the other seven species. All species collected have a wide distribution: either worldwide in tropical/subtropical waters (*T.furcifera*, *L.bipartitus*, *L.massa*, *B.fimbriatula*), worldwide in tropical and temperate waters (*M.striata*, *L.pedicellatus*) or in Indo-Pacific tropical/subtropical waters (*Lyrodus* sp. V, *Nausitora globosa*) [2,3]. *T.furcifera*, *L.bipartita* and *L.pedicellatus* are found all around Australia whilst the other species are restricted to our northern waters [3,9,10]. All species collected in this study have previously been reported from north Queensland [3,10,11].

Teredinid borers, commonly known as shipworm or teredo, excavate tunnels lined with calcium carbonate to accommodate their elongate bodies which, in some species, can be up to 2m long. They feed on cellulose, possibly supplemented by fungi or plankton [12] and continue to bore through their life, lengthening and widening their burrows [2]. Settling larvae are only 200-300 μ m in diameter [13] and a corresponding area of exposed wood is all that is required for infection. Initial penetration is either with or across the grain but by a depth of one body diameter teredinids generally turn to burrow with the grain [6,14]. Deviation from this course results if obstructions or other tunnels are met [5]. The external aperture to the burrow remains small (1-2mm) [2] and gives no indication of the size of the internal tunnels.

The Australia-New Guinea teredinid fauna is the richest in the world with 38 of 66 known species occurring here and only 3 of 14 known genera absent [9]. No Australian region can be considered safe from teredinid attack [3]. Tropical areas are particularly susceptible as warmer sea temperatures permit breeding and settlement throughout the year. The diversity of species is also higher and growth rates up to 2.5 times greater than those at higher latitudes [3,15].

Teredinid damage to the balsa blocks was typical of their general boring characteristics in that:

- (i) only small areas were required for infection as seen by the ready penetration through cracks in the polyester resin coating on block edges,
- (ii) burrows were almost always aligned with the grain, and
- (iii) impediments to progress were avoided, notably the PVA glue lines and GRP coating.

The absence of soft remains of any of the borers suggests they had died long before panels were removed from exposure. In tropical regions salinity is considered the main limit on teredinid breeding and distribution [3,15] and can also cause adult mortality [16,17]. Salinities at the study site were over 30ppt for most of the study period but dropped during the wet season (Feb-Apr) to a minimum of 17ppt in March [18]. This drop may have caused the apparent mortalities. Lack of reinfestation of the blocks could be due to interference of fouling growth with renewed settlement [19].

Martesia striata, a representative of the second family of boring molluscs, the Pholadidae, excavates a burrow a little bigger than its shell and this is only enlarged as required [20]. The burrow is mainly for protection as the animal feeds exclusively on plankton [20]. Animals can reach 50mm in length and 20mm in diameter [2,21]. The largest specimens collected in the balsa blocks were 25mm long.

As *M.striata* and other pholads do not require wood for nutrition, these animals could conceivably bore into PVC foam of a similar density to wood. However, unlike the teredinids, pholads do not bore deep into the substrate and any damage would be confined to outer layers. There was no sign of *Martesia* attack in the foam-cored blocks examined after 19 months immersion.

b. Fouling

The external surfaces of the GRP showed no evidence of damage caused by fouling growth and the GRP had no unusual effect on fouling composition. The GRP performed as any hard, smooth, non-toxic substratum immersed in the sea and rapidly accrued a cover of diverse organisms.

c. Minehunter Implications

Results from balsa wood samples indicate the possible dangers in using this material for Minehunter construction, particularly if hull damage goes undetected for any length of time.

5. ACKNOWLEDGEMENTS

Panel exposures and inspections were performed by Mr J. Hill (Joint Tropical Trials and Research Establishment, Innisfail). Radiographs of test blocks were prepared by Mr W. Hemmy and Mr F. Gold (Metallurgy Division, MRL).

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PLATES

Plate 1 Radiographs of GRP-balsa test blocks.

- a. undamaged, full immersion
- b. minor damage, full immersion
- c. major damage, full immersion
- d. major damage, half immersion

Plate 2 Cut faces through test blocks showing molluscan borer tunnels.

- a. undamaged, full immersion
- b. minor damage, full immersion
- c. major damage, full immersion
- d. major damage, half immersion

Plate 3. Radiographs of GRP-foam test blocks

- a,b 'Airex' foam
- c,d 'Klegecell' foam

Table 1 Balsa-cored panels returned to MRL for examination

Degree of Damage	Degree of Immersion		
	Full	Half	Tidal
Major	2	2	-
Minor	2	-	-
Undamaged	2	-	-
Painted	-	-	-

Table 2 Fouling abundance (mean \pm standard deviation) on blocks with different degrees of damage and immersion.

Degree of Immersion	Degree of Damage	%Fouling Cover (mean \pm s.d.)	Fouling Dry Wt (gm/dm ²)
Full	Undamaged	97.3 \pm 2.5	3.15 \pm 2.89
	Minor	98.8 \pm 1.9	3.81 \pm 0.87
	Major	96.0 \pm 1.8	2.03 \pm 1.02
Half	Major	51.5 \pm 17.1	0.04 \pm 0.02

Table 3 Mean percentage cover (\pm s.d.) of organism groups in order of decreasing abundance on fully immersed test blocks.

Organism Group	Percentage Cover (mean \pm s.d.)
Molluscs	24.17 \pm 9.21
Compound ascidians	17.00 \pm 13.73
Red algae	14.25 \pm 8.79
Sponges	13.83 \pm 13.18
Brown algae	10.33 \pm 10.22
Barnacles	8.92 \pm 5.65
Organic slime	8.92 \pm 4.38
Hydroids	5.00 \pm 5.29
Erect bryozoans	3.42 \pm 7.52
Encrusting bryozoans	3.25 \pm 3.39
Green algae	2.58 \pm 3.03
Tubeworms	1.75 \pm 1.71
Blue-green algae	1.08 \pm 3.75
Solitary ascidians	0.17 \pm 0.39
TOTAL	97.3 \pm 2.2

Table 4 Mean percentage cover (\pm s.d.) of organism groups on half-immersed test blocks.

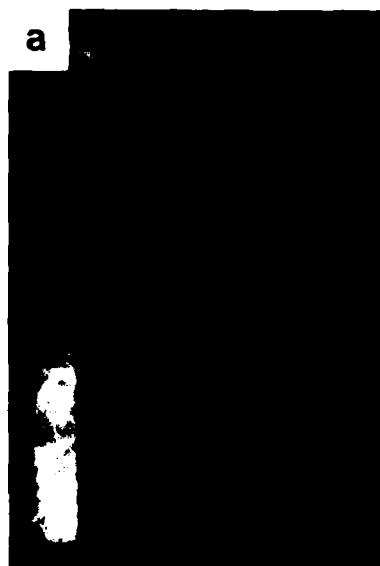
Organism Group	Percentage Cover (mean \pm s.d.)
Organic slime	33.25 \pm 14.38
Brown algae	8.75 \pm 3.50
Blue-green algae	7.25 \pm 8.85
Red algae	1.00 \pm 2.00
Green algae	1.00 \pm 0.82
TOTAL	51.5 \pm 17.1

Table 5 List of the molluscan borers identified from pallets and shells recovered from the test blocks.

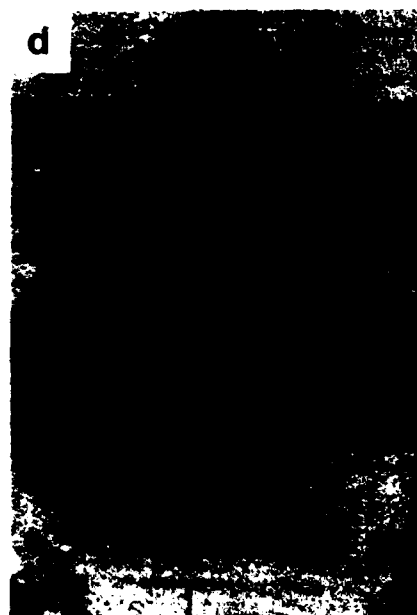
Species	Test Blocks			
	D0-100	D1-100	D2-100	D2-50
Family Pholadidae				
<i>Martesia striata</i> (Linnaeus)			+	+
Family Teredinidae				
<i>Teredo furcifera</i> von Martens			+	
<i>Lyrodus pedicellatus</i> (Quatrefages)	+		+	
<i>L.bipartitus</i> (Jeffreys)	+		+	+
<i>L.massa</i> (Lamy)			+	
<i>Lyrodus</i> sp.V (sensu Marshall Ibrahim [2])		+	+	+
<i>Nausitora ? globosa</i> (Sivickis)	+			+
<i>Bankia fimbriatula</i> Moll & Roch		+	+	
TOTAL	3	2	7	4

Table 6 Extent of borer damage (mean \pm s.d.) to test blocks with different degrees of damage and immersion.

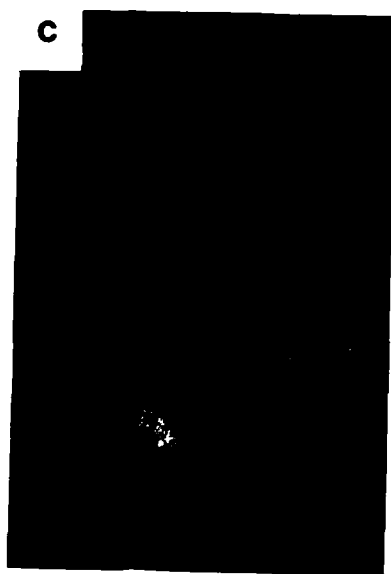
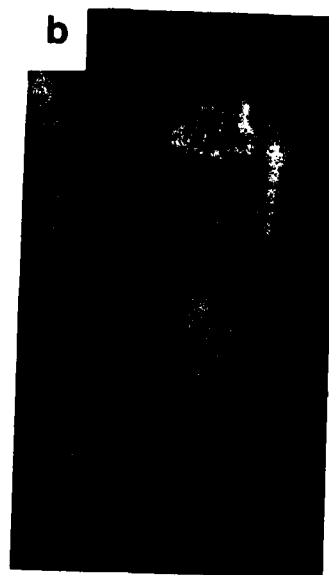
Degree of Immersion	Degree of Damage	Tunnel Nos/ Cut face	% Wood Loss
Full	Undamaged	23.5 \pm 5.0	7.19 \pm 2.51
	Minor	18.8 \pm 10.3	7.56 \pm 2.25
	Major	78.5 \pm 34.0	16.69 \pm 6.03
Half	Major	25.4 \pm 11.5	5.40 \pm 0.14



50mm



50mm



50mm

APPENDIX A

CORE MATERIALS USED IN PANEL CONSTRUCTIONS

1. Airex R62/130 grade closed cell PVC foam. Manufactured in Switzerland and supplied by Plastral Trading Pty Ltd., Melbourne. Nominal density 130 kg/m^3 .
2. Klegecell H130 grade closed cell PVC foam. Manufactured in France by KRP Plastique and supplied by Australian Klegecell Co., Sydney. Nominal density 130 kg/m^3 .
3. Balsa wood imported from Papua-New Guinea and supplied by Australian Balsa Co. Pty. Ltd., Melbourne. Density : 170 kg/m^3 .

APPENDIX B

GRP SKINS : MATERIALS AND LAY-UP

1. RESIN SYSTEM

- (a) Resin: Cellobond A2785CV isophthalic polyester resin, manufactured by Kemrez Chemicals, Melbourne under licence from BP Chemicals Ltd.
- (b) Accelerator : Cobalt naphthenate as a 6% solution in white spirit supplied by RF Services, Melbourne.
- (c) Catalyst : Methyl ethyl ketone peroxide, NF Grade, as a 40% solution in dimethyl phthalate (available oxygen 9.5 - 10.0%) manufactured by Interlox Chemicals Pty. Ltd. and supplied by RF Services, Melbourne.

Ratios of catalyst and accelerator were varied slightly depending on the temperature at the time of laminating, but were usually around 1.5% catalyst and 0.5% accelerator solution (volume/volume).

2. GLASS REINFORCEMENT

- (a) Chopped strand mat, 300 g/m². ACI Emulsion Mat 100, manufactured by ACI Fibreglass, Melbourne.
- (b) Woven roving, 600 g/m². Woven by Colan Products, Sydney, with a silane (Type 2) finish and supplied by RF Services, Melbourne.

3. SKIN LAY-UP

The GRP skins consist of alternating layers of chopped strand mat (CSM) and woven roving (WR) with a layer of CSM as the initial layer against the foam. The final laminate (for each skin) consists of seven layers of CSM and seven layers of WR.

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